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Effects of different management practices on Collembola and Acarina in corn production systems

II. The effects of moldboard plowing and atrazine[1])

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With 10 figures

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1. Introduction

This report is the second of a two-part study conducted at Michigan State University tillage effects and herbicide treatments in corn plots (Moore *et al.* 1984).

Studies which involve the role of soil arthropods in organic decomposition, nutrient :ling, and soil humidification, have shed light on their importance to agroecology (Thomp-n 1924; Engelmann 1961; Franz 1962; Witkamp & Crossley 1966; Butcher *et al.* 71; and Lebrun 1979). Cognizance of this importance has necessitated more precise in-:stigations of current agricultural practices and their effects on soil arthropod populations.

Our objective in this study was to compare the effects of conventional tillage and atra-:e on populations of soil Acarina and Collembola. Quantitative comparisons were made tween field populations in grassland plots and treated plots.

Summarized below are the treatments evaluated in this study:

(I) Conventional tillage, using the moldboard plow, and no application of herbicide. is is the principal tillage method in Michigan. Soil is broken, turned over, and completely)rganized to a depth of 22.9—25.4 cm. It is usually the deepest and most distruptive til-:e practice employed in our agriculture. Used at medium soil moisture levels, it surpasses other implements in loosening soil, while incorporating crop residues, manure, fertili-:s or lime. Energy requirements are relatively high because of the large volume of soil)ved (Robertson *et al.* 1977a).

(II) Conventional tillage (moldboard plow), cultivation (Robertson *et al.* 1977b), with e application of atrazine (AAtrex®). The general use of atrazine is to control broad leaf d grassy weeds in corn, sorghum, sugarcane and turf grass sod. It is absorbed through e roots and foliage, translocated acropetally in the xylem, and accumulated in the apical :ristems and leaves of plants. It acts as a photosynthetic inhibitor, affecting the photo-emical activity of the chloroplasts (Hill reaction; Audus 1964).

The term "cultivation" is used vaguely in the literature. In this report the term "culti-tion" is defined as any mechanical manipulation of soil for agricultural purposes.

2. Methods and materials

Samples taken from a series of plots, each 6.1 m × 15.2 m, on which corn was grown. The plots d seven treatments in four replicates (only two treatments are reported here). Each replicate d a grassland counterpart, added to the experimental design after plots were established. The l is Celina loam (soil management group 2.5a) and supported Canada brome grass (*Bromus pur-us* L.) for eight years. This soil tends to be high in fertility and available water capacity. Runoff slow to medium, and permeability moderately slow. Treatments were initiated during May 1979

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(plowed-May 11, planted-May 15). Atrazine was applied June 12 at a concentration of 0.47 ccm^{-2} and cultivation was done June 22. During the investigation, water was supplemented by sprinkler irrigation five times; 12.7 mm — June 26; 25.4 mm — June 28, July 18; and 38.1 mm — July 27.

Samples were taken approximately every three weeks from the following plots: grassland, plowed plus no weed control, and plowed plus herbicide. Samples in the form of soil cores, 6 cm diameter $\times$15 cm deep, were collected using a compression reducing coring device. Five cores were taken from each treated and grassland plot in all four replicates. Cores were taken in-row between plants, near the central portion of each plot to avoid edge effects. Samples were bagged in plastic, placed in a cooler chest, and taken back to the laboratory. Arthropods were extracted using Tullgren funnels. Soil cores were broken up into chunks and spread evenly over wire mesh screens. The funnel's heat source were 25-watt bulbs connected to a rheostat. Low settings were used to prevent the soil from drying too rapidly, thus trapping the arthropods.

Soil was extracted four or five days, depending on inital temperature and moisture levels of the soil (soil too moist or cold required lower heat and longer extraction time). Extracted animals were both collected and preserved in a solution of 95% ethanol — 1% glycerine.

Following extraction, Collembola were identified according to Snider (1967), and Christiansen & Bellinger (1980, 1981). Acarina were identified according to Kranz (1978) and from keys provided at the Ohio State University summer Acarology program 1980 (unpublished). Statistical analysis of data followed the methods utilized by Moore *et al.* (1984).

3. Results

Extraction efficiency was reported by Moore *et al.* 1984.

Treatment comparisions were based on quantitative analysis of population densities of two major arthropod orders: Acarina and Collembola. Of 51 genera identified, only two Collembola and one genus in each of the three major soil inhabiting suborders of Acarina (Prostigmata, Cryptostigmata and Mesostigmata) were collected in numbers large enough to make any statistically valid conclusions. When compared with grassland, overall significant decreases ($P \leq .05$) occurred in Collembola populations in treated plots (Fig. 1.) Individual analysis showed these decreases continued through the first four sample dates. No significant differences among treatments were observed on any sample date. Population levels of Collembola in grassland control plots increased steadily from June 9, reaching a maximum August 3. This was followed by a steady decrease, reaching a minimum September 23. Treated plots fluctuated little, within a few data points, over the entire growing season, increasing slightly from October to November.

Brachystomella parvula (Schaeffer), a hemiedaphic species (Fig. 2), showed overall significant decreases in treated plots compared with grassland, and exhibited the same general patterns as total Collembola. Individual sample date significance ($P \leq .05$) ended after three sample dates. Maximum and minimum levels were reached on the same sample dates as total Collembola.

Population levels of *Tullbergia granulata* Mills, an euedaphic species (Fig. 3), did not exhibit overall significant differences between treatments and grassland for the first two sample dates. On the remaining six dates, significant differences ($P \leq .05$) existed among treatments, with the atrazine treatment higher than without atrazine. Significant differences ($P \leq .05$) between atrazine treatment and grassland appeared on sample dates September 23, October 14, and November 1, with atrazine treatment populations higher than grassland. A significant difference ($P \leq 0.5$) was detected on November 1 between treatment and grassland, grassland populations were lower.

Population levels of *T. granulata* in grassland plots fluctuated little throughout the eight sample dates, with no definite maximum or minimum. Both treated plots had a maximum on November 1, and exhibited no apparent minimum.

Overall, Acarina populations decreased significantly in plowed plots ($P \leq .05$). Individual analysis (Fig. 4) showed significant differences ($P \leq .05$) between plowed and grassland, grassland populations higher on each sample date except August 26. Decreases in atrazine were significant ($P \leq .05$) on all sample dates except August 26 and December 9.

Acarina populations in grassland plots increased steadily from June 9, and reached a maximum August 3. This was followed by a steady decrease, reaching a minimum August 26. Treatment levels fluctuated little over the entire growing season.

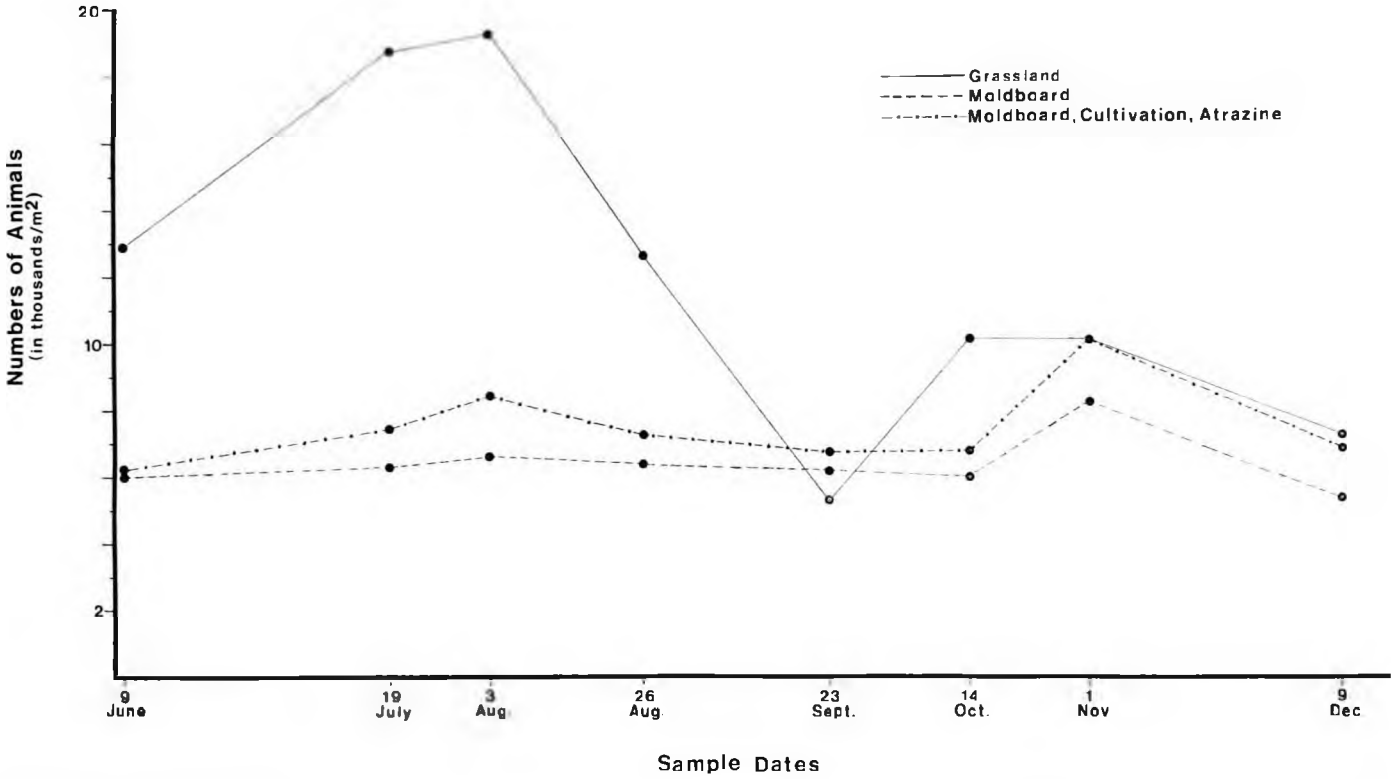

Fig. 1. Mean population levels of Collembola collected from moldboard plowed, moldboard plowed with atrazine added, and grassland.

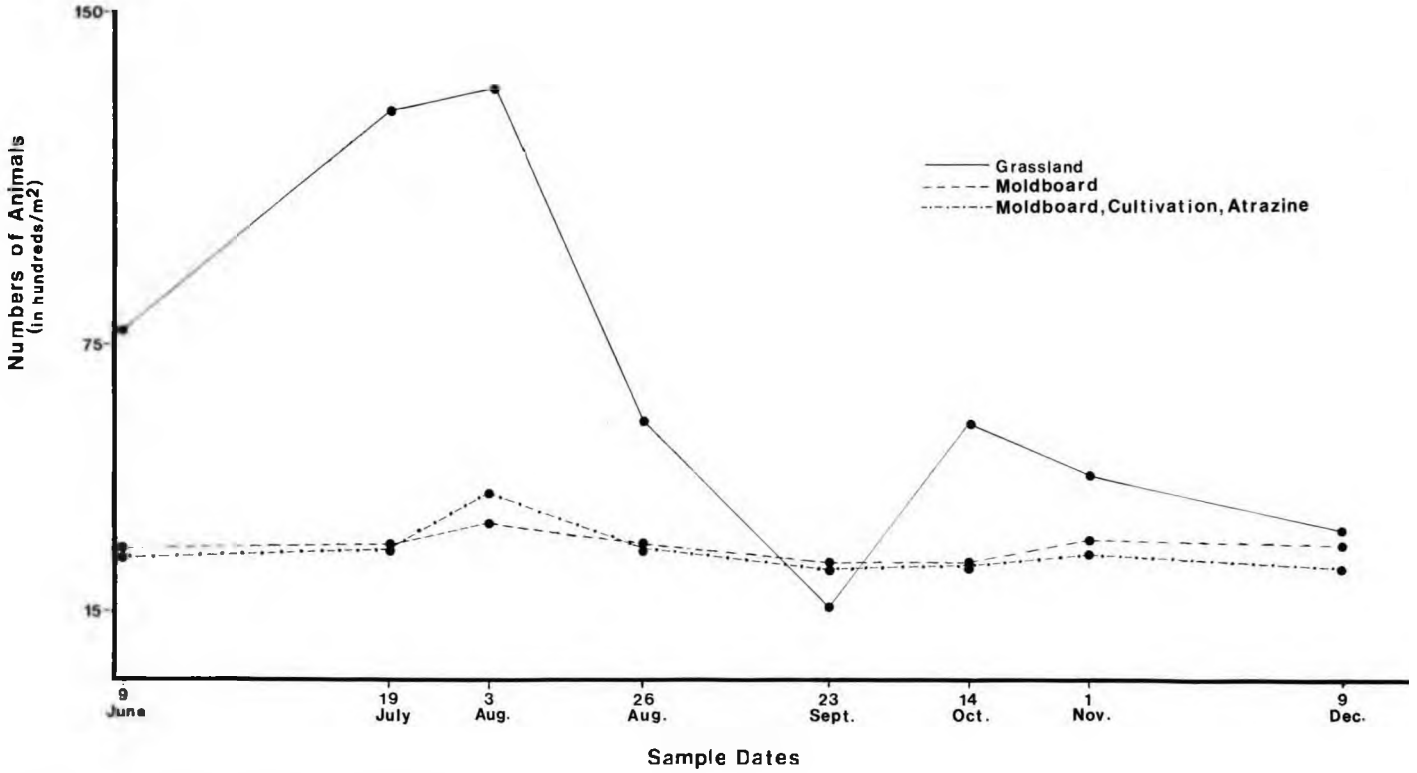

Fig. 2. Mean population levels of *Brachystomella parvula*.

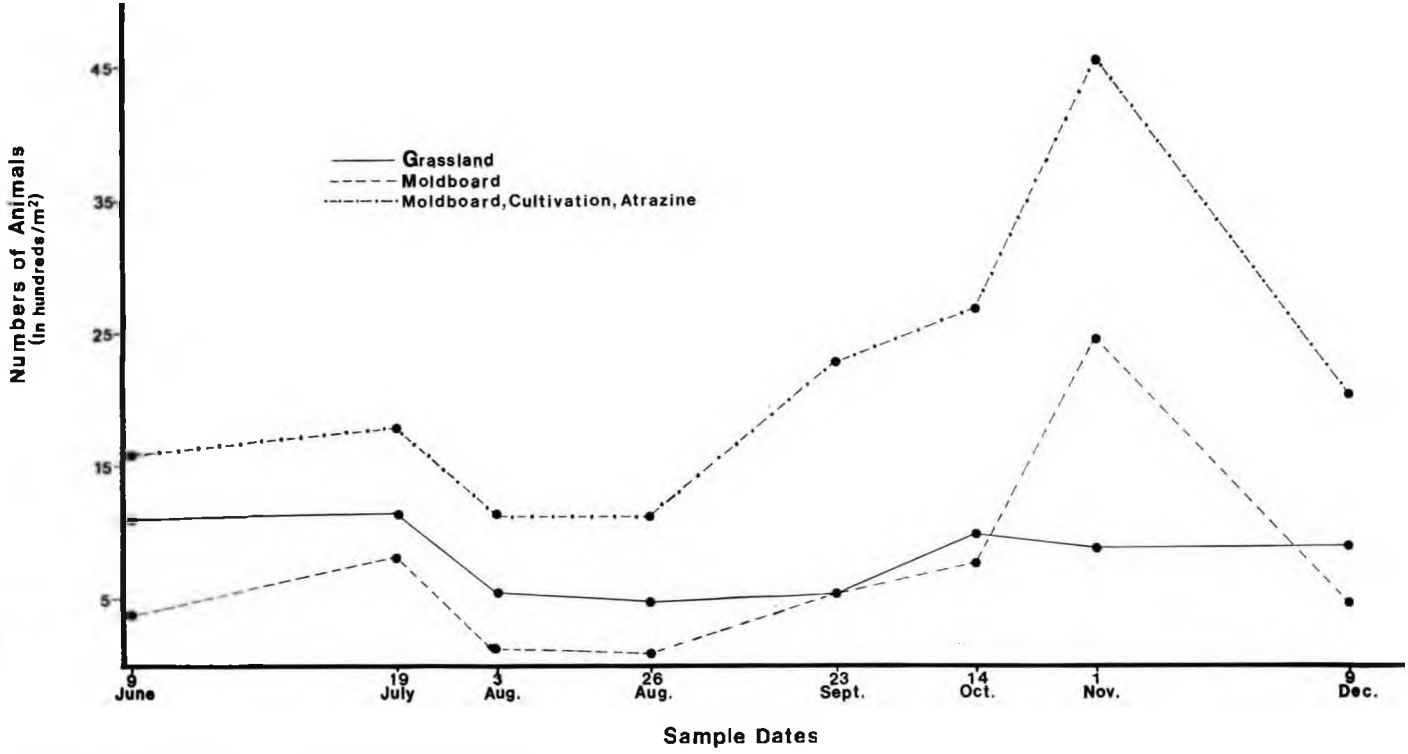

Fig. 3. Mean population levels of *Tullbergia granulata*.

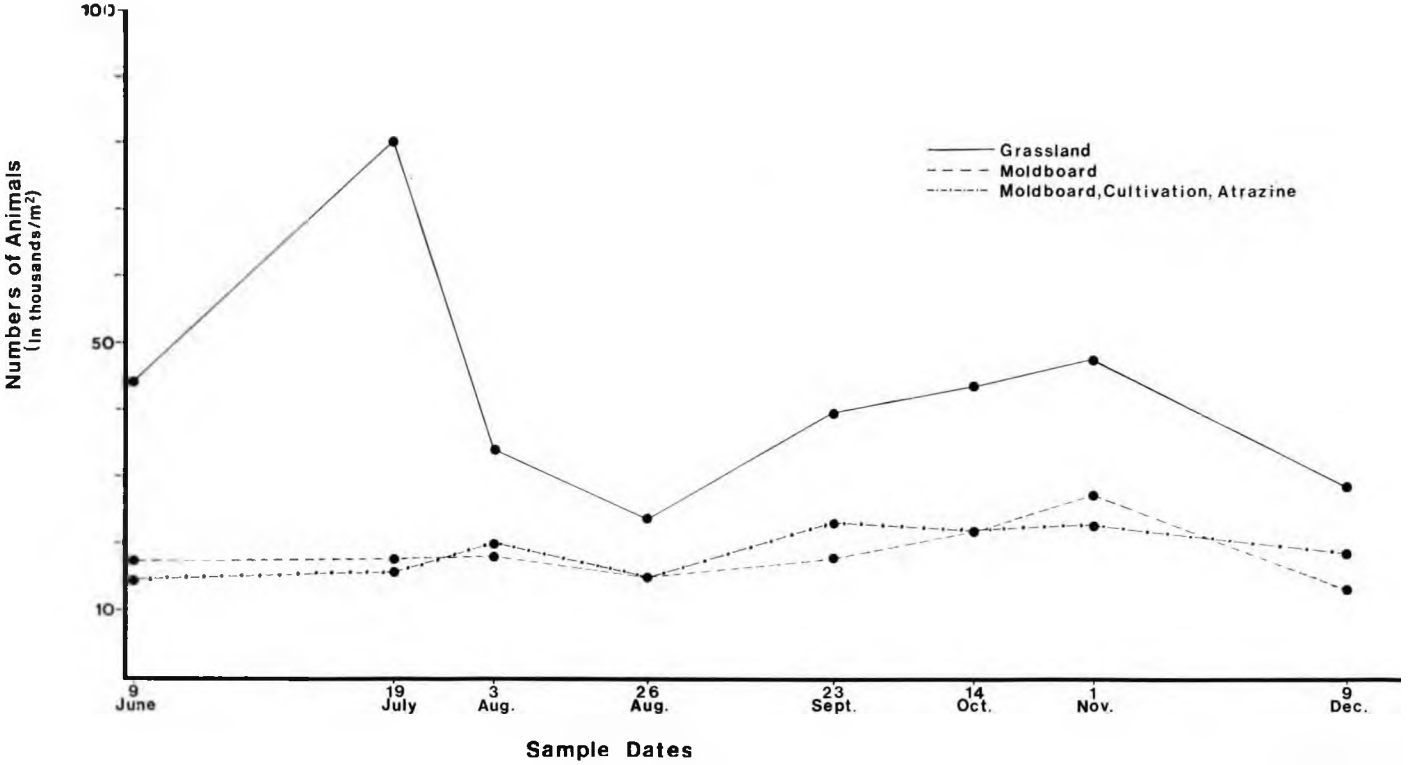

Fig. 4. Mean population levels of Acarina.

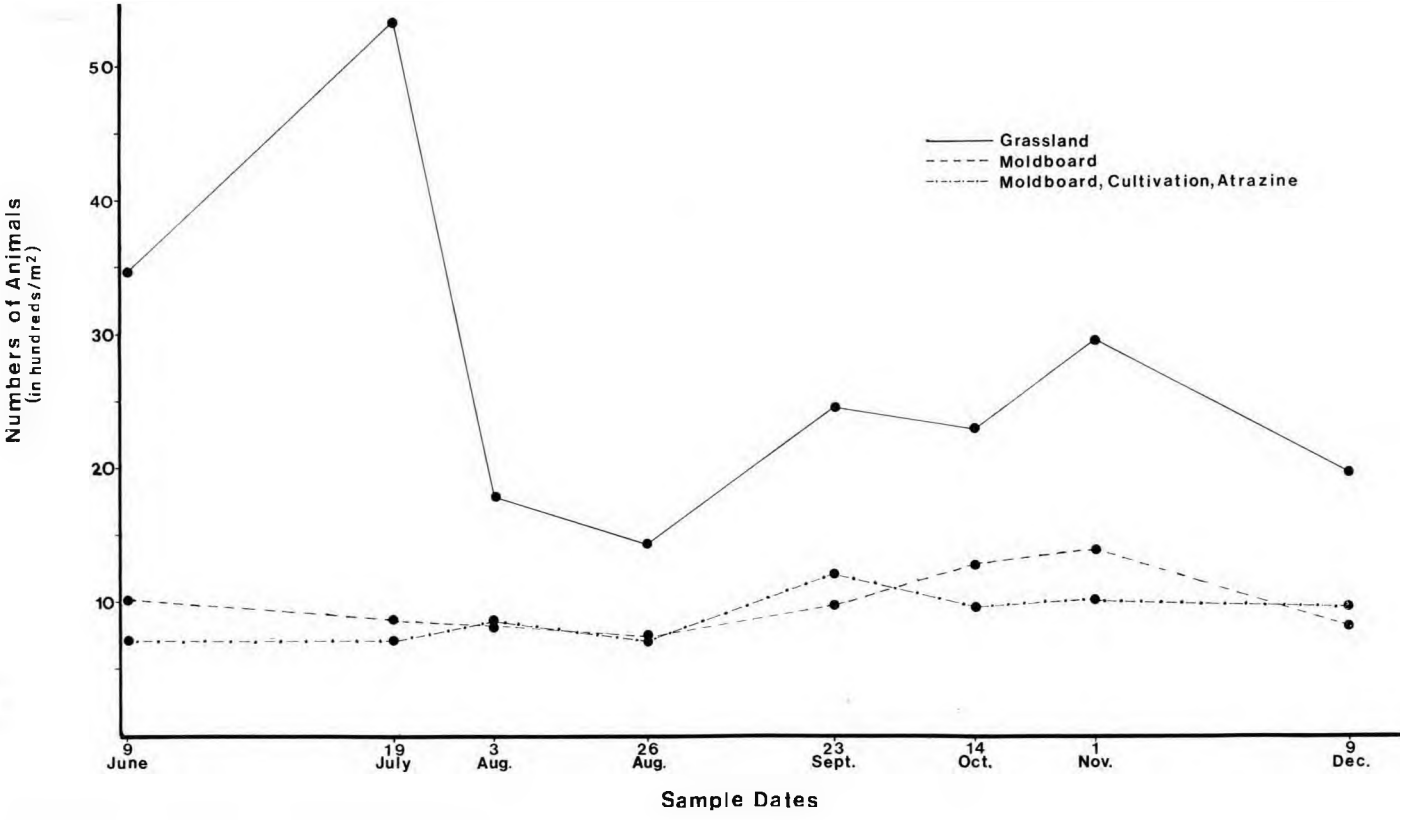

Fig. 5. Mean population levels of Prostigmata.

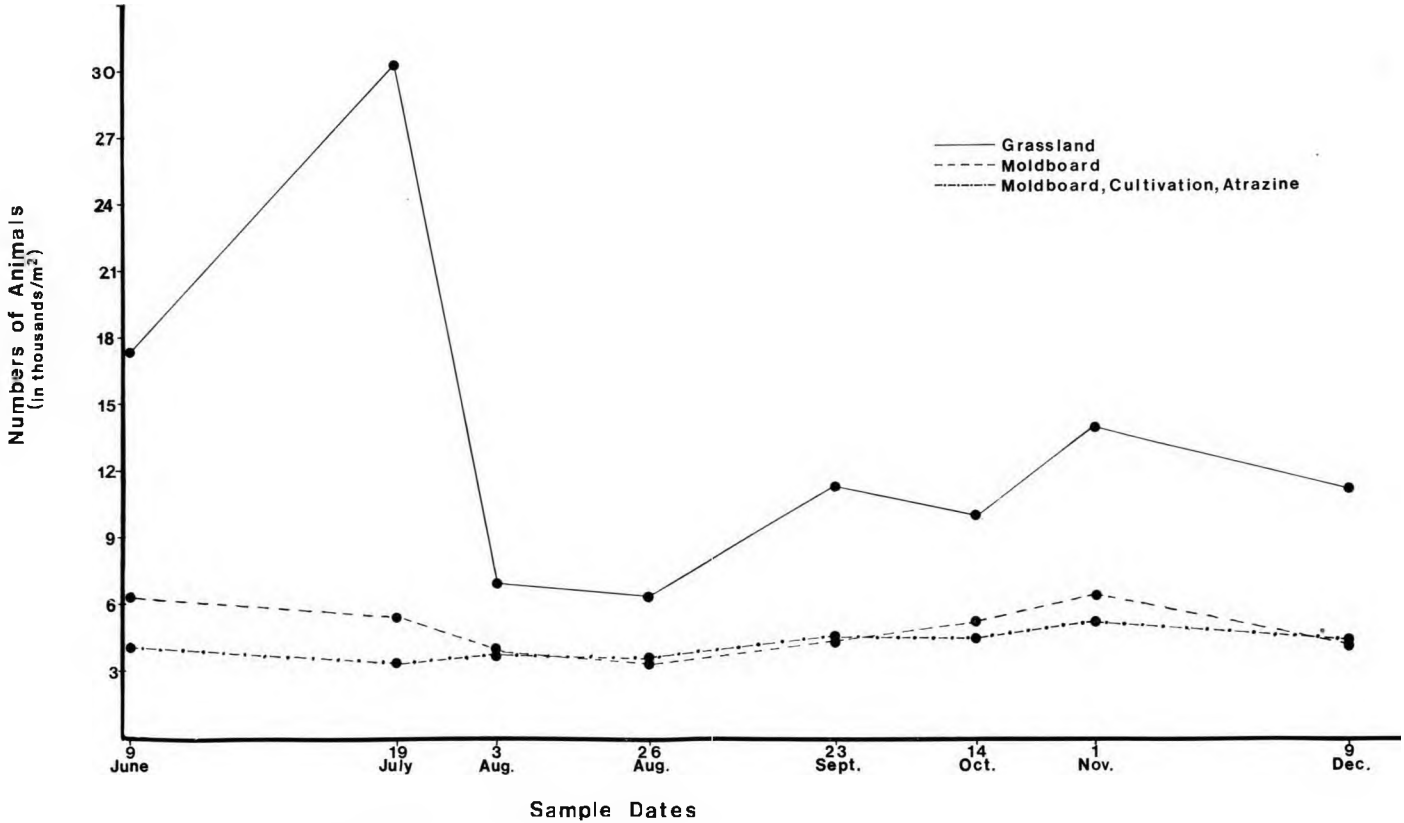

Fig. 6. Mean population levels of *Bakerdania* sp.

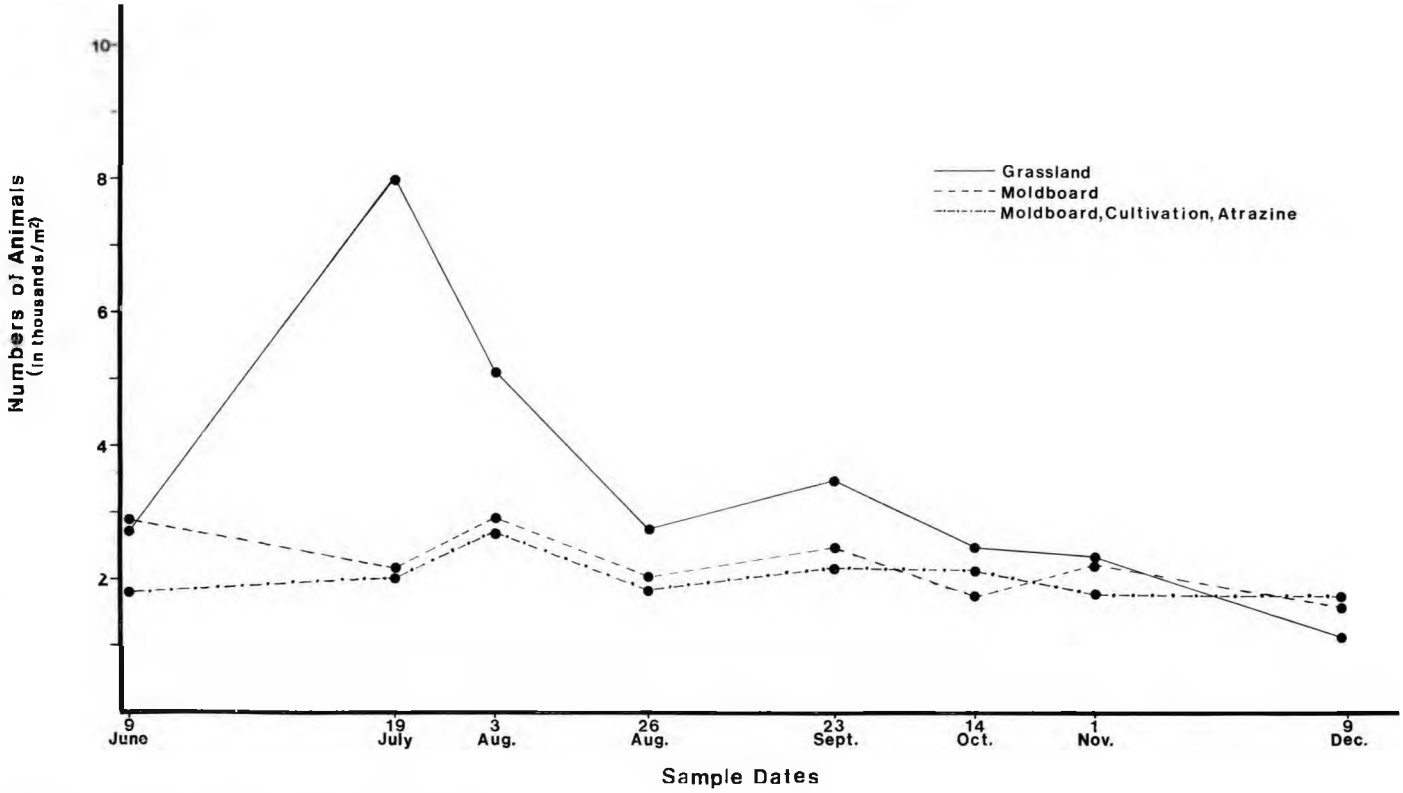

Fig. 7. Mean population levels of Mesostigmata.

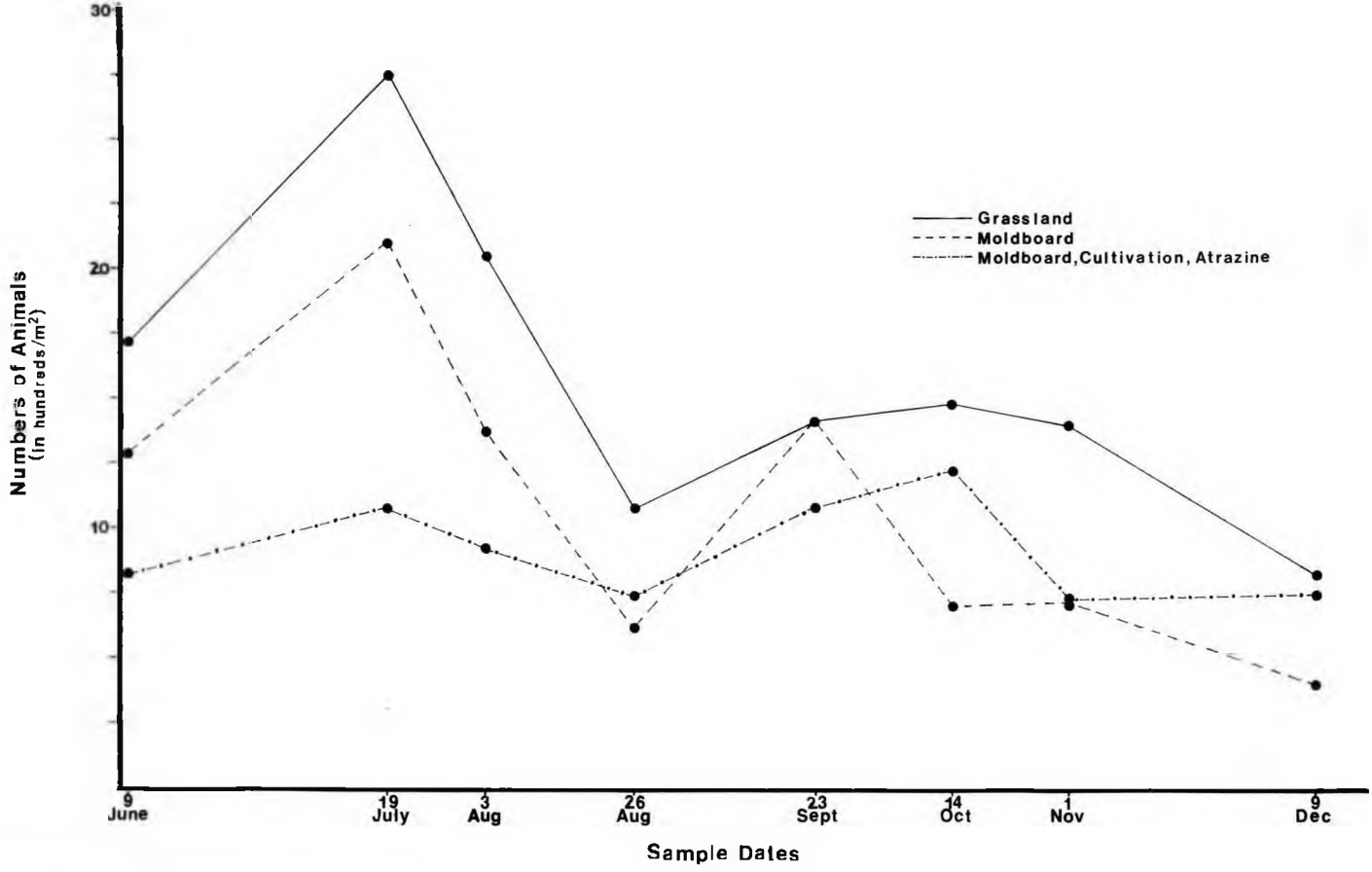

Fig. 8. Mean population levels of *Rhodacarellus* sp.

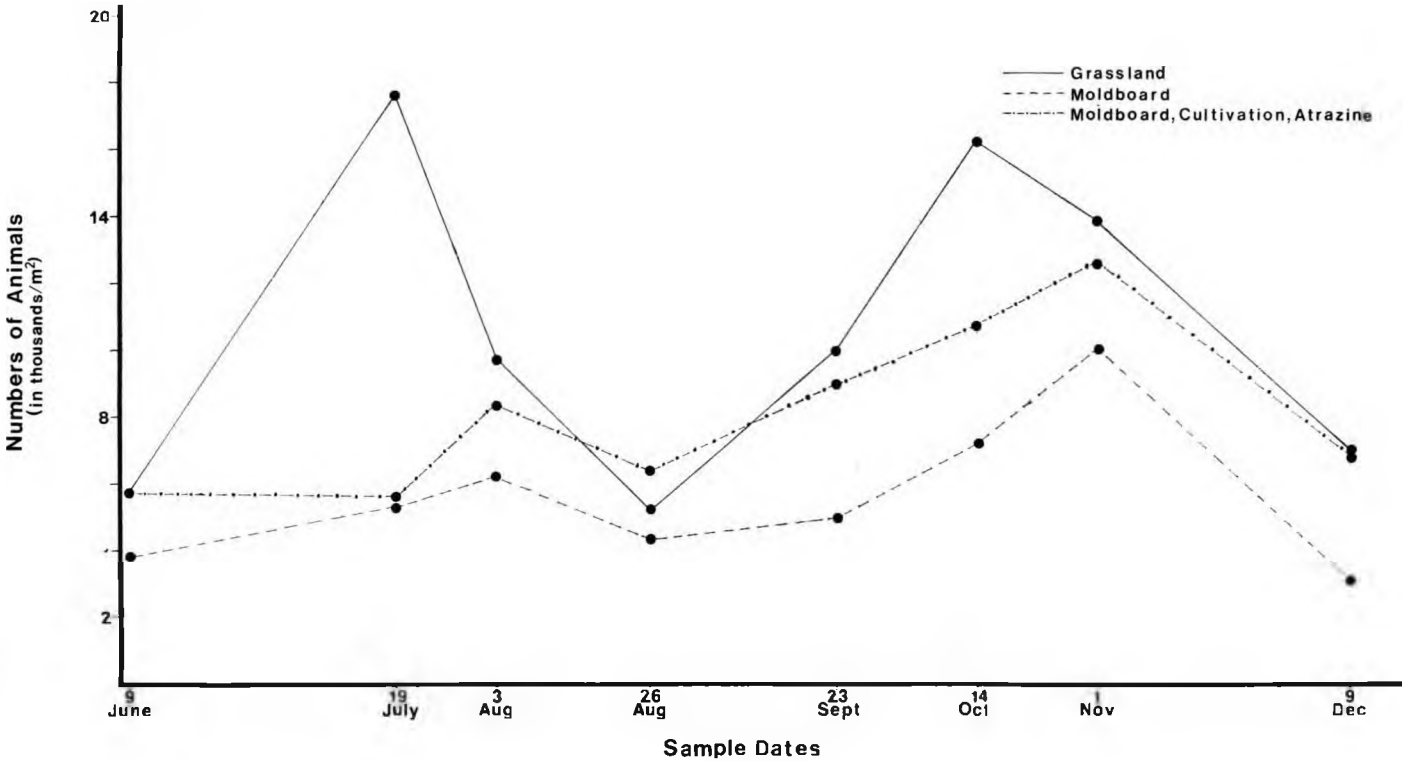

Fig. 9. Mean population levels of Cryptostigmata.

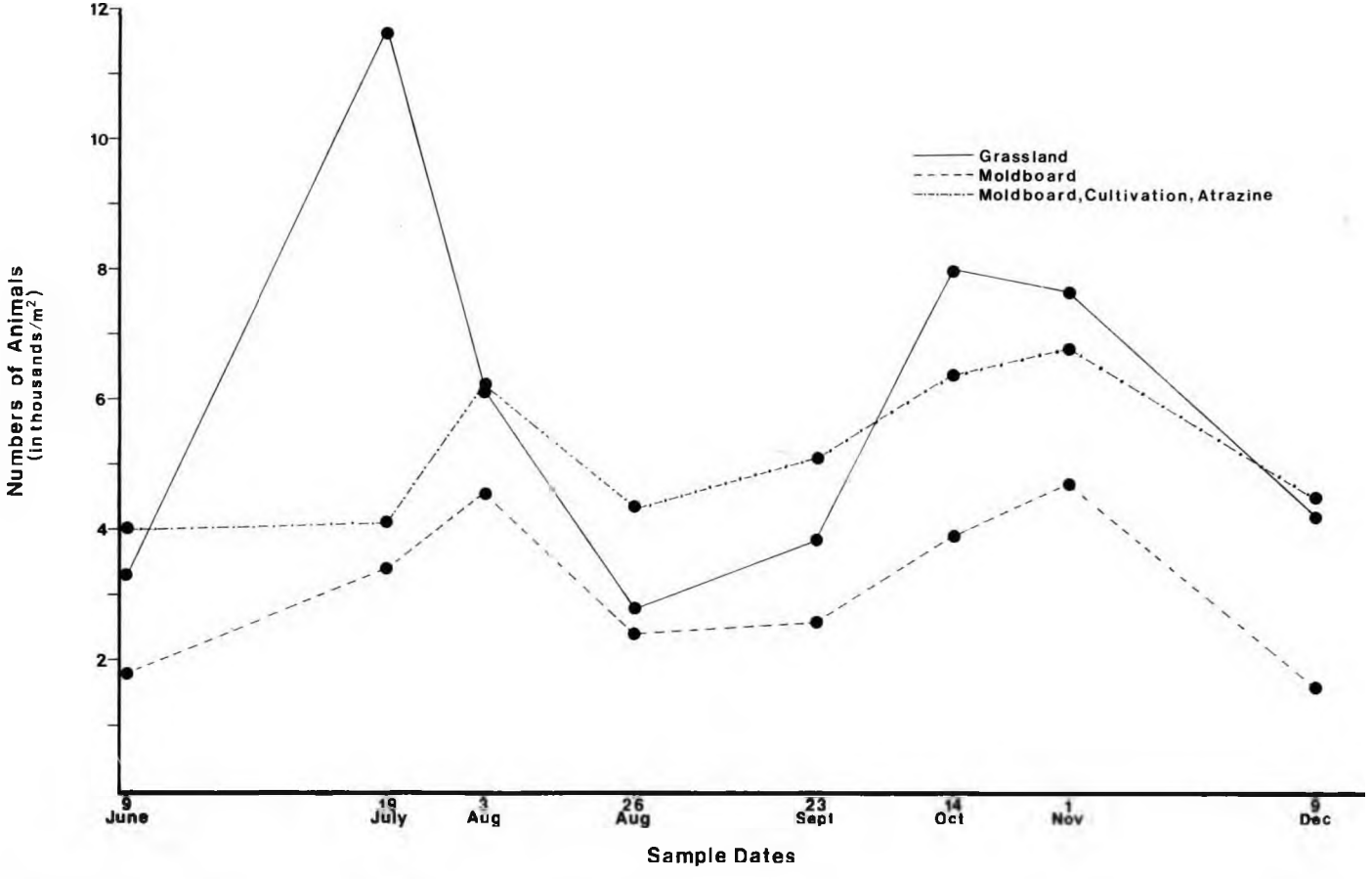

Fig. 10. Mean population levels of *Oppiella* sp.

The suborder Prostigmata and *Bakerdania* sp. (Figs. 5 & 6) exhibited significant decreases ($P \leq .05$) in plowed plots compared with grassland. Individual significant differences, maximum and minimum of grassland, and treatment population levels, displayed the same pattern as total Acarina, with the exception of *Bakerdania* sp. on August 3. No significant differences between the grassland and plowed occurred on this date.

Mesostigmatid mites (Fig. 7) decreased significantly in plowed plots ($P \leq .05$), however, individual significant differences occurred only on July 19 and August 3. Reaching a maximum July 19, grassland populations decreased steadily through the remainder of the growing season, while treatment levels fluctuated little.

Individual significant differences ($P \leq .05$) occurred in populations of *Rhodacarellus* sp. (Fig. 8) between plowed only and grassland on October 14, and between plowed with atrazine treatment and grassland July 19 and August 3, with grassland levels higher for both. *Rhodacarellus* sp. did not exhibit overall differences between treatments and grassland. Plowed populations were significantly higher than atrazine treatment on July 19, and displayed populations peaks July 19 and September 23. Atrazine treatment reached a maximum October 14.

Compared with grassland, overall decreases of Cryptostigmata populations in treated plots were significant ($P \leq .05$). Individual analysis of samples (Fig. 9) showed decreases in plowed which occurred on July 19, September 23, and October 14. Decreases in populations from atrazine treatment were significant ($P \leq .05$) on July 19 and October 14. Significant differences among treatments occurred on September 23, with atrazine treatment populations higher.

Population levels of grassland peaked twice over the growing season, with a maximum occurring July 19 and October 14, and minimum September 23. Treatment levels fluctuated over several data points, but never enough to display a distinct maximum or minimum.

Oppiella sp. (Fig. 10) displayed no significant differences between plowed treatment and grassland on September 23, or between atrazine treatment and grassland on October 14. Population peaks in grassland plots were similar to total Cryptostigmata. Maxima of treatment populations occurred August 3 and November 1, with a minimum September 23. Except for the above two dates, *Oppiella* sp. displayed the same overall, and individual significant differences as total Cryptostigmata.

4. Discussion and conclusions

4.1. Cultivation effects

Cultivation effects on soil fauna are easily recognized by comparing grassland and arable land (Tischler 1955). Arable land is usually poorer in most soil faunae than uncultivated land in numbers of individuals and species (Buckle 1921; Kevan 1962; Burnett 1968; Edwards & Lofty 1969; and Edwards & Thompson 1973). However, certain soil animals, such as Symphyla, Protura, Diplopoda, Rhodacaridae (Mesostigmata), sminthurid Collembola and prostigmatid mites are more abundant in agricultural soils than elsewhere (Edwards & Lofty 1969). An important reason for faunal differences between arable and grassland, is that grassland supports vegetation during a period when arable land is fallow. The presence of vegetation ensures a food source that is always available for a large majority of soil species (Buckle 1921).

In this study, population levels of Acarina and Collembola in grassland increased in June, with maxima occurring in July for Acarina and in August for Collembola. However, trends in natural population levels of these soil animals show a great deal of variation with respect to seasonal fluctuations. Thompson (1924), Ford (1937, 1938), and Dowdy (1965) found Acarina and Collembola populations peaked during winter months, November through February Dhillon (1962) reported peaks in June, with minimum levels in December. Edwards & Thompson (1975) found population maxima during spring and fall. Shaddy & Butcher (1977) reported no distinct population peaks.

Tullbergia granulata also exhibited variations with respect to its seasonal fluctuations. In this study, *T. granulata* populations fluctuated little, and did not display any distinct maximum or minimum levels. USHER (1970) found *T. granulata* peaked September through October, while SHADDY & BUTCHER (1977) reported peaks in July. Numerous ecological factors, such as variations in soil type, climatic conditions, moisture regimes, and the frequency and quantity of samples taken may contribute to these discrepancies.

TISCHLER (1955), SHEALS (1956), and EDWARDS & LOFTY (1969, 1975) reported reduction of soil animal populations immediately following cultivation. Some taxa are affected more than others. EDWARDS & LOFTY (1969) report Prostigmata, Mesostigmata and Symphyla are least affected, while Cryptostigmata, hemiedaphic Collembola and Pauropoda are reduced after plowing. BURNETT (1968) claims that cultivation increased Collembola and mite populations. ALEINIKOVA & UTROBINA (1975) report that the method of cultivation has no appreciable effect on the total numbers of group diversity, but considerably effects the ratio of individual groups.

Conventional tillage, utilizing the moldboard plow in this study significantly reduced populations of Acarina and Collembola immediately following its use. However, contrary to the findings of EDWARDS & LOFTY (1969), Prostigmata were significantly reduced over the entire growing season. Cryptostigmata initially showed no response to tillage, and exhibited significant reductions on only three of eight sample dates.

An important indirect effect of cultivation is the change it causes in pre-existing plant cover. Altering the vegetation cover can greatly change the structure of soil animal populations within one horizon and soil type (BLOCK 1966). STRICKLAND (1947) showed that considerable differences exist between qualitative populations on two plots of similar soil type largely due to different plant associations on the plots. Changing the vegetation cover will change quality of soil organic matter. This in turn effects the faunal composition. Changes in fauna may effect the quality of humus produced, thus effecting soil fertility.

EDWARDS & LOFTY (1969) reported that after six months numbers of soil animals in treated and untreated plots differed only slightly, indicating cultivation effects may not persist into a second growing season. SHEALS (1956) showed that reseeding cultivated land resulted in rapid recolonization by Collembola, but populations of Cryptostigmata and Mesostigmata remained low over a period of 17 months. Cultivated land left fallow may result in persistent reduced numbers of soil animals (SHEALS 1957). BUTCHER *et al.* (1971) report the effects of cultivation on soil animals may persist up to three years. Arthropods with short life cycles dwindle when soil is first cultivated, but they usually recover within a single growing season. By contrast, arthropods that live longer than a year may be affected by cultivation longer than one growing season (EDWARDS & LOFTY 1969; EDWARDS & THOMPSON 1973).

In this study, after seven months, no recovery to levels comparable to grassland were observed for total Acarina or Prostigmata. Cryptostigmata began to recover after five months, while Mesostigmata recovered after just three months. Levels of *Rhodacarellus* sp. (Mesostigmata) increased initially following tillage, and displayed the same pattern as grassland populations over the first five sample dates. This increase in *Rhodacarellus* sp., and quick recovery of Mesostigmata in general, may be attributed to their predatory behavior. They range freely through soil, and are not restricted to specific horizons in the soil to the degree of other euedaphic mites.

Populations of Collembola, with the exception of *Tullbergia granulata*, began to recover after four months. *T. granulata* populations were not detrimentally affected by tillage. Their levels remained nearly equal to grassland levels, and even increased to levels significantly higher than grassland after five months.

4.2. Herbicide effects

Experiments with atrazine show pronounced sensitivity of the soil fauna to the action of this herbicide (POPOVICI *et al.* 1977). SUBAGJA & SNIDER (1981) found that Brewers yeast treated with atrazine, and fed to *Folsomia candida* and *Tullbergia granulata* caused signi-

ficant mortalities at 5,000 ppm. It also caused longer instar duration and reduced egg production. Fox (1964) and Edwards & Thompson (1973) showed atrazine decreased numbers of Collembola and mites. Popovici *et al.* (1977) report that reduction of atrazine effects on soil animals after four months is significant for restoring their equilibrium.

The effects of atrazine on populations of Acarina and Collembola in this study are difficult to assess. The majority of taxa analyzed showed no differences between cultivated plots with and without atrazine. Tillage, being so great a destructive force on soil animals, has masked any apparent effects of the herbicide. Between cultivated plots with and without atrazine, a few taxa exhibited significant differences. Cryptostigmata, *Oppiella* sp. and *Rhodacarellus* sp. all had one sample date where these differences occurred. However, these differences were probably the result of high natural variation that occurs in soil animal populations owing to their non-random, aggregated distribution (Hughes 1962; Nef 1962; and Berthet & Gerard 1965).

Only *Tullbergia granulata* displayed consistently distinct differences between cultivated plots with and without atrazine, thus exposing possible herbicide effects. After the first two sample dates, populations of *T. granulata* increased significantly higher than grassland or plowed only levels. This is indicative of possible stimulation of *T. granulata* populations caused by atrazine usage, and is in direct contrast to studies by Subagja & Snider (1981), Fox (1964) and Edwards & Thompson (1973). They found atrazine decreased Collembola populations. Reason for these discrepancies are not readily apparent, but demonstrate the need for further investigations into possible herbicide stimulation of soil fauna.

Before concluding, an important consideration should be made. Although some taxa exhibited levels equivalent to grassland in December, the final sample date, the assumption that total recovery of Acarina and Collembola population has occurred should not be made. In subsequent months, grassland populations may increase steadily while treated plots may continue to remain at low levels. Only continuous sampling through subsequent months can reveal long-term effects of these treatments.

5. Zusammenfassung

[Wirkungen verschiedener Wirtschaftsmaßnahmen auf Collembola und Acarina in Mais-Produktions-Systemen.

II. Die Wirkungen von Bodenwendung und Atrazin.]

Der Einfluß der Bodenbearbeitung mit dem Pflug und Atrazinbehandlung auf Populationen von Kleinarthropoden wurden (vergleichend) bewertet.

Bodenproben wurden regelmäßig während einer Wachstumsperiode von Versuchsparzellen mit Mais und von unbebauten Grasparzellen (Kontrolle) entnommen. Quantitative Unterschiede der Milben- und Collembolen-Populationen in behandelten und unbehandelten Kontrollparzellen wurden bewertet. Alle Bodenbearbeitungsmaßenahmen verursachten anfangs eine signifikante Verminderung der Milben- und Collembolen-Populationen. Die Erholung der Populationen auf das Niveau der Kontrollparzellen variierte bei den verschiedenen Ordnungen und Unterordnungen der Kleinarthropoden. Mesostigmata-Populationen erreichten das Niveau der Kontrollpopulationen binnen dreier Monate. Collembola und Cryptostigmata erholten sich nach je vier bis fünf Monaten. Prostigmata, sowie die Gesamtzahl der Milben, zeigten am Ende der Wachstumsperiode keine Anzeichen der Wiederherstellung des ursprünglichen Besatzes.

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The effects of tillage, using the moldboard plow, incorporated with atrazine treatment upon soil microarthropod populations were evaluated.

Soil core samples were taken regularly during one growing season from experimental test plots containing corn and from grassland plots. Quantitative differences in acarine and collembolan populations from treated and grassland plots were evaluated. All tillage treatments caused acarine and collembolan populations to be significantly reduced initially. Population recovery to control levels differed among the various orders and suborders of soil microarthropods. Mesostigmata populations recovered to control levels in three months. Collembola and Cryptostigmata populations showed signs of recovery after four and five months respectively. Prostigmata and total Acarina failed to show any signs of recovery at the end of the growing season.

Key words: Arthropods, Collembola, moldboard plow, populations, atrazine, soil, Acarina.